SIGMA for Seamless Handover in Space

Dr. Mohammed Atiquzzaman

University of Oklahoma

Norman, OK 73019-6151

atiq@ou.edu

Team Members: (Past/Present)

- Pulak K Chowdhury (Univ of Oklahoma)
- Abu Sayeem Reaz (Univ of Oklahoma)
- Swapna Gurumani (Univ of Oklahoma)
- Shaojian Fu ((Univ of Oklahoma -> OPNET)
- Justin Jones (Univ of Oklahoma -> Risk Metrics)
- Sirendra Sivagurunathan (Univ of Oklahoma -> yousendit.com)
- Liran Ma (Univ of Oklahoma -> GWU)
- Yong-Jin Lee (Woosong Univ., Korea)
- William Ivancic (NASA Glenn Research Center)
- Harsha Sirisena (Univ of Canterbury, New Zealand)

Outline of this talk

- Introduction
- Handovers in satellite networks
- Classification of current handover schemes
- Drawbacks of Mobile IP
- SIGMA
- SIGMA in space (simulation)
- Results
- Future Work

Introduction

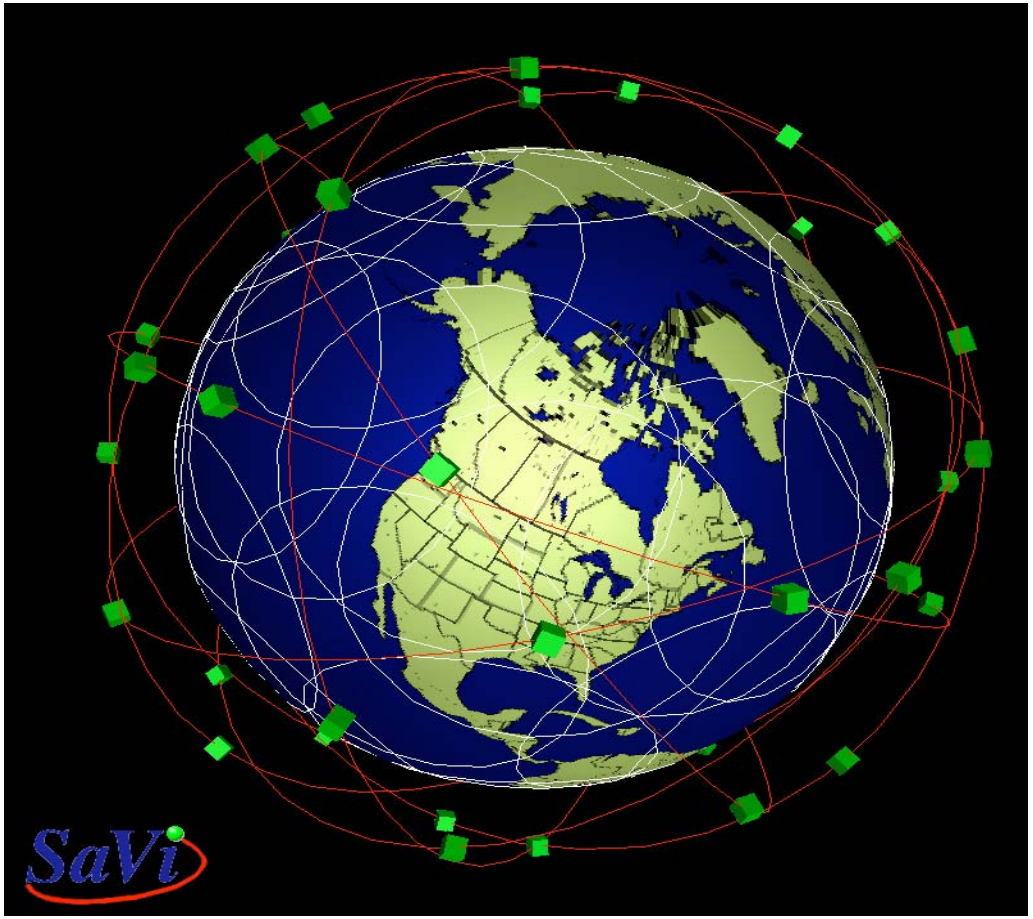
- Future space communications will be based on IP technology and satellites.
- Three types of satellites
  - Ÿ Geostationary Earth Orbit (GEO)
  - Ÿ Medium Earth Orbit (MEO)
  - Ÿ Low Earth Orbit (LEO)
- LEO satellites will be an integral part of future space based data communications
  - Ÿ Lower propagation delay
  - Ÿ Lower power requirements
  - Ÿ More efficient spectrum allocation
- LEO satellite connections encounter frequent handovers

Handovers in satellite IP networks

- Transfer of a connection to a new spotbeam or satellite is called *handover*.

- Link Layer handover
  - Spotbeam handover
  - Satellite handover
  - Link handover

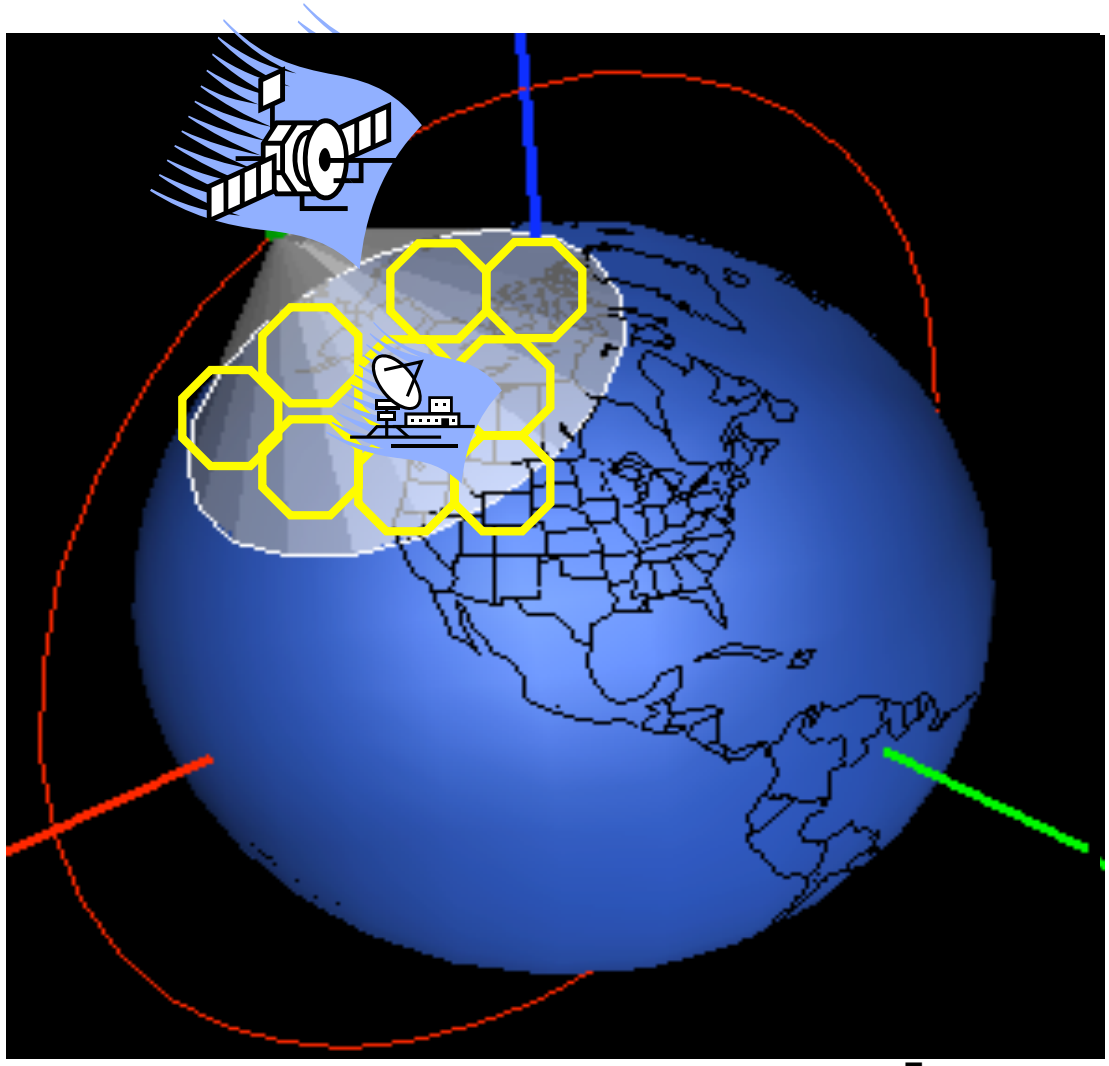
- Network Layer handover
  - Satellite as a router
  - Satellite as a mobile host



A Globalstar design, with 48 active satellites in 8 planes of 6.

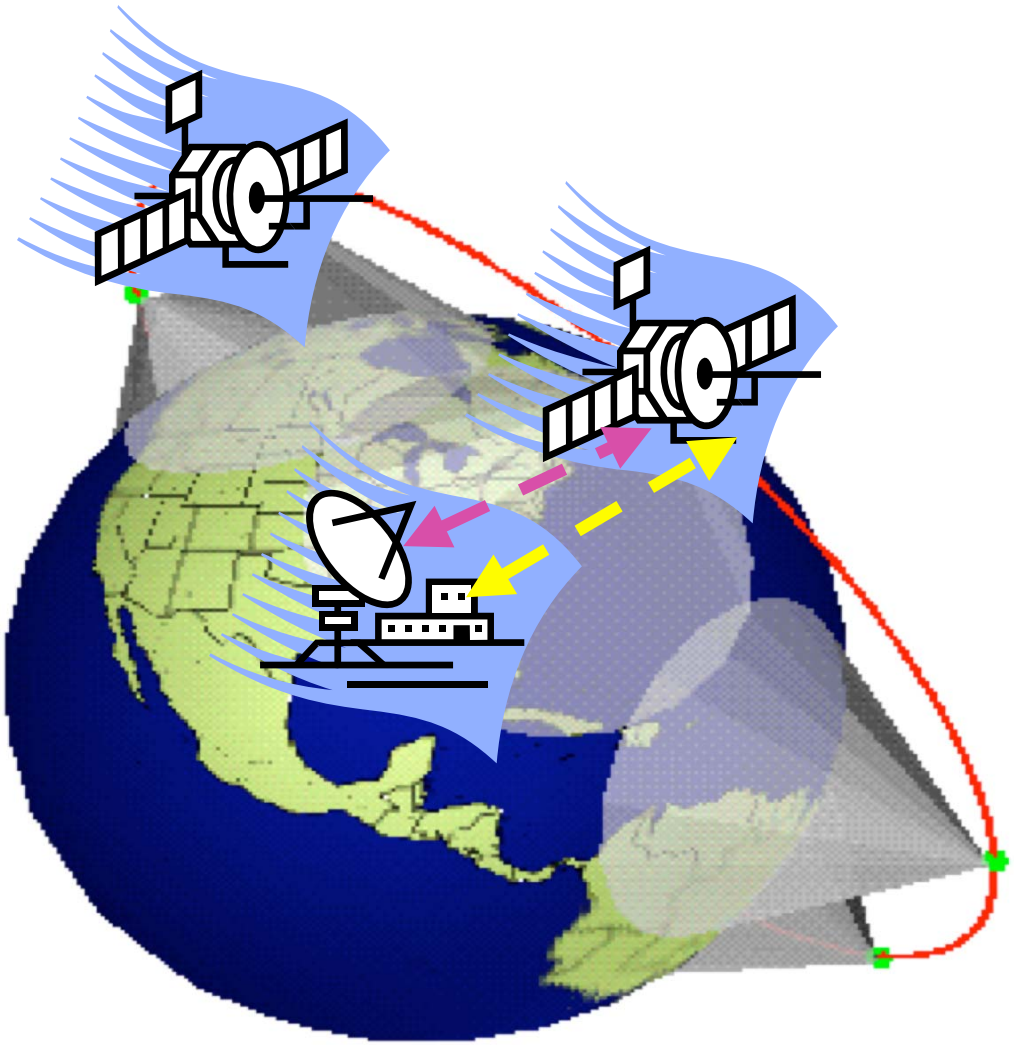
Spotbeam handover

- Spotbeam handover
  - Ÿ existing connection transferred to neighboring spotbeam.
- Similar to intra-switch handover for terrestrial mobile networks.



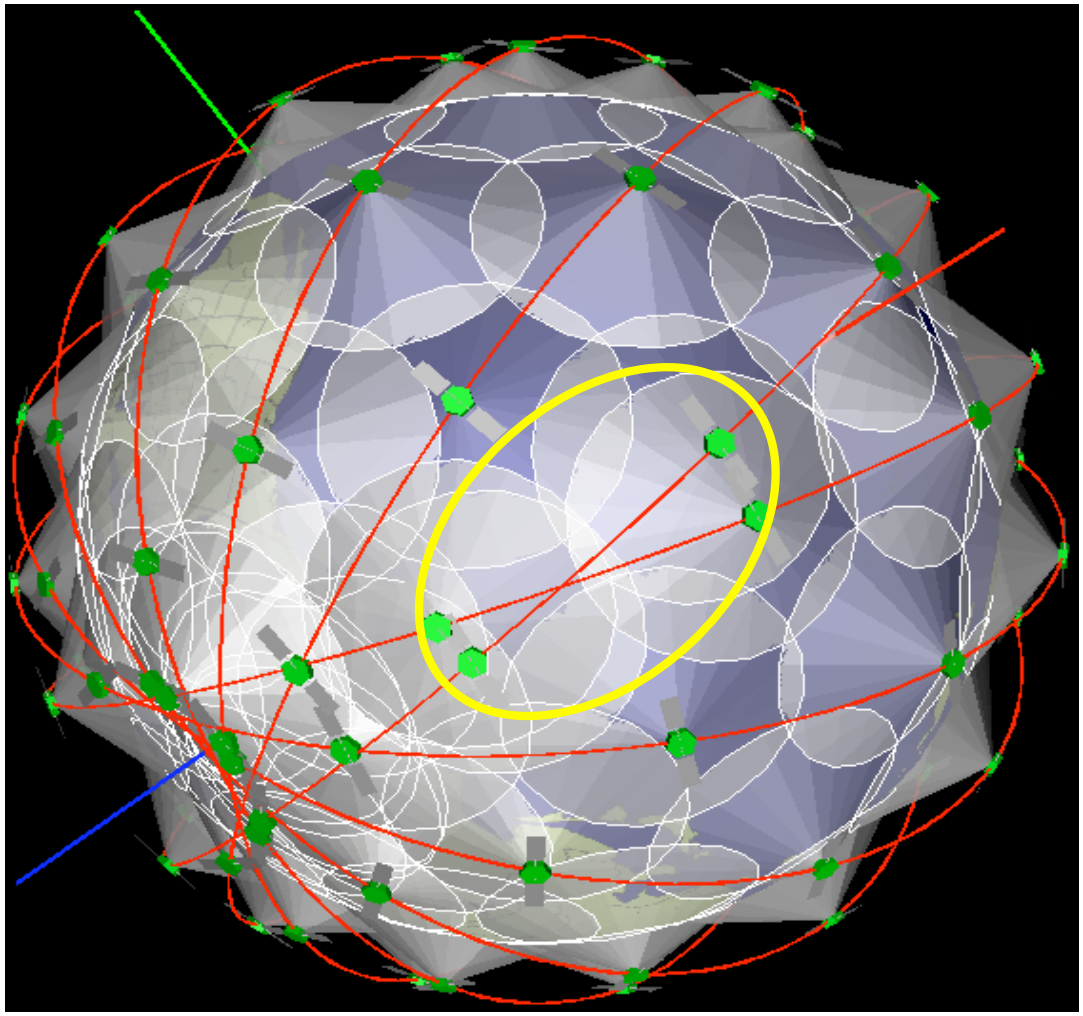
Satellite handover

- Movement of satellite causes it to be handed over between ground stations.
- Similar to inter-switch handover in the case of terrestrial mobile network.



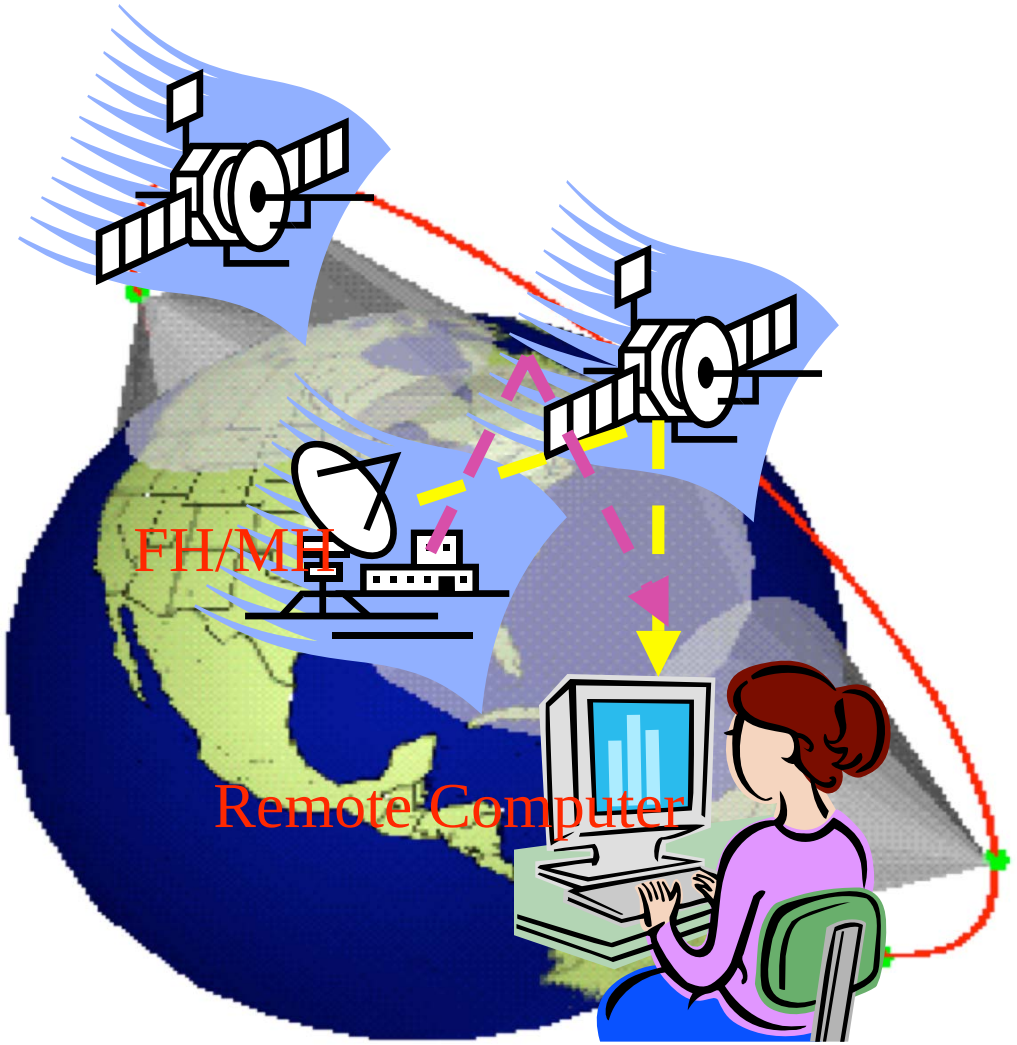
Link handover

- Iridium design
  - Ÿ 96 active satellites in 8 planes of 12.
- Dynamic connectivity structure due to satellite movement
  - Ÿ requires rerouting on-going connections to new Inter-satellite Links (ISL).



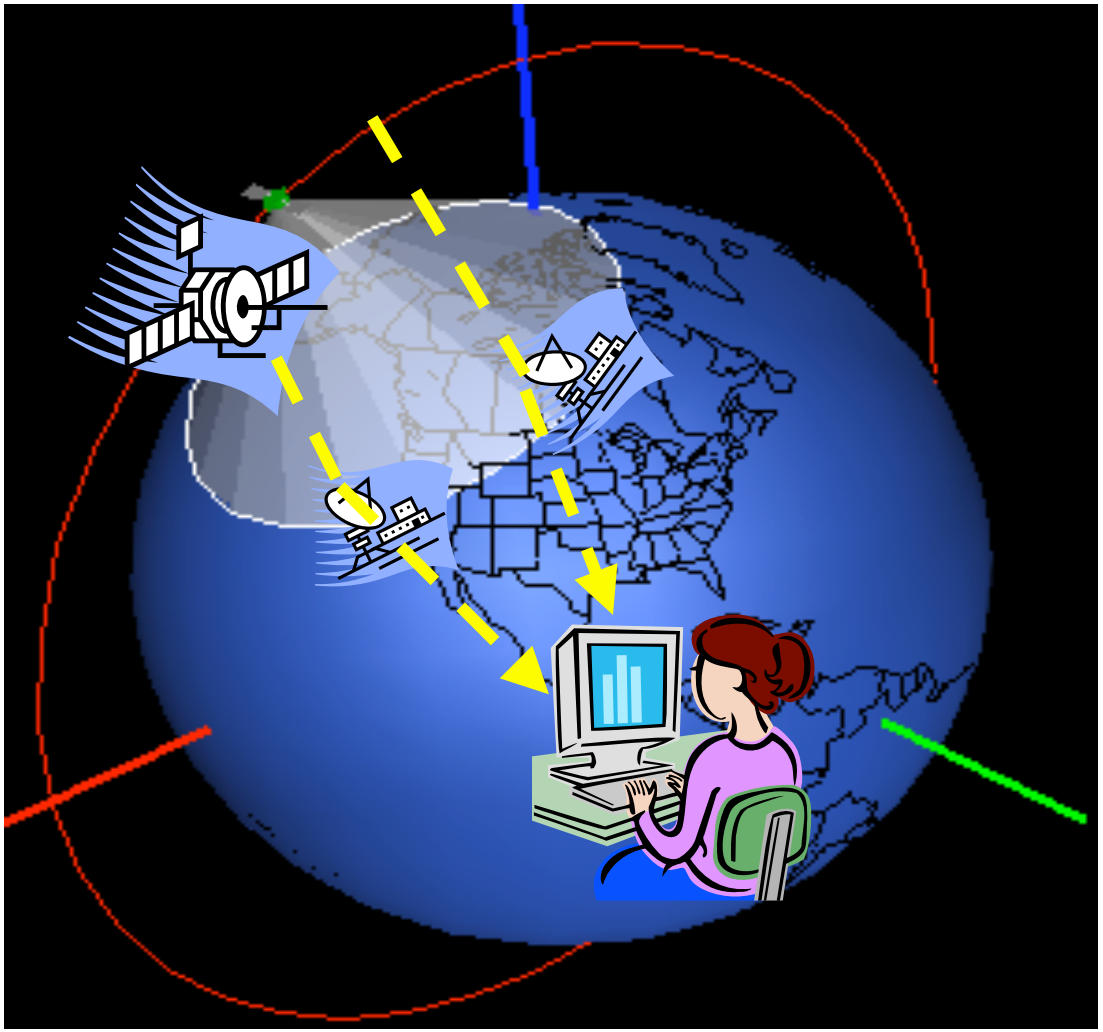
Network Layer handover
Case 1: satellite as a router

- Satellites act as IP routing devices.
  - Ÿ No on-board device generating or consuming data
- Satellites allocated different IP prefix.
- FH/MH need to maintain continuous connection with Remote Computer.



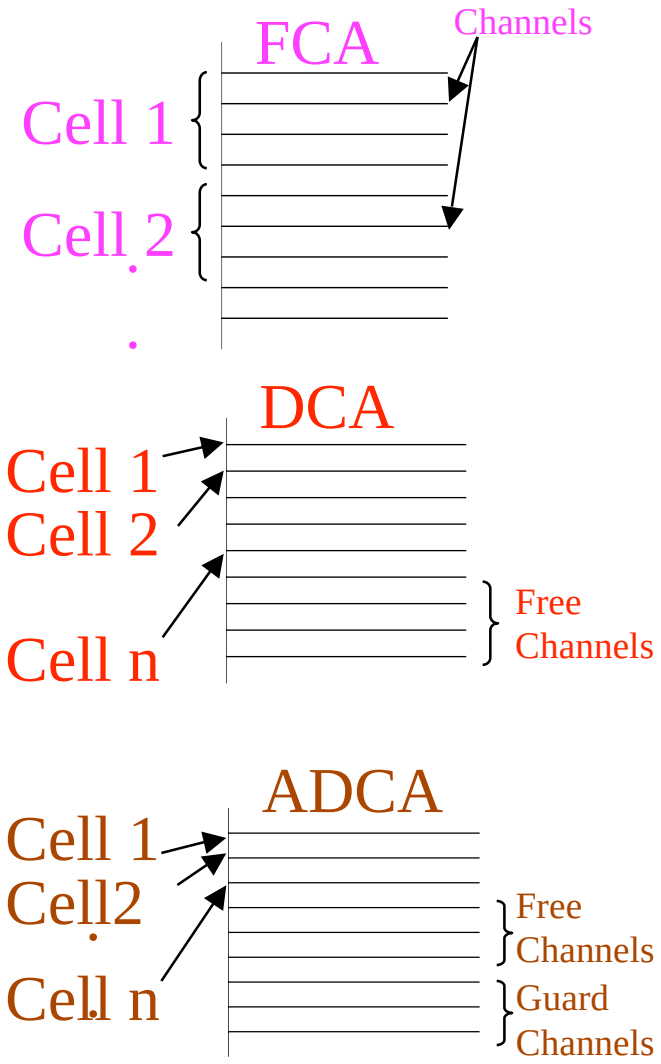
Network Layer handover
Case 2: satellite as a mobile host

- Satellite onboard equipments act as the endpoint of the communication.
- Ground stations are allocated with different IP prefix.
- Satellite need to maintain continuous connection with remote computer.



Spotbeam Handover Schemes: Classification

- Classification
  - Channel allocation strategies
  - Handover guarantee
- Based on channel allocation strategy
  - Fixed Channel Allocation (FCA) Schemes
  - Dynamic Channel Allocation (DCA) Schemes
  - Adaptive Dynamic Channel Allocation (ADCA) Schemes
- Based on handover guarantee
  - Guaranteed Handover (GH) Schemes
  - Prioritized Handover Schemes



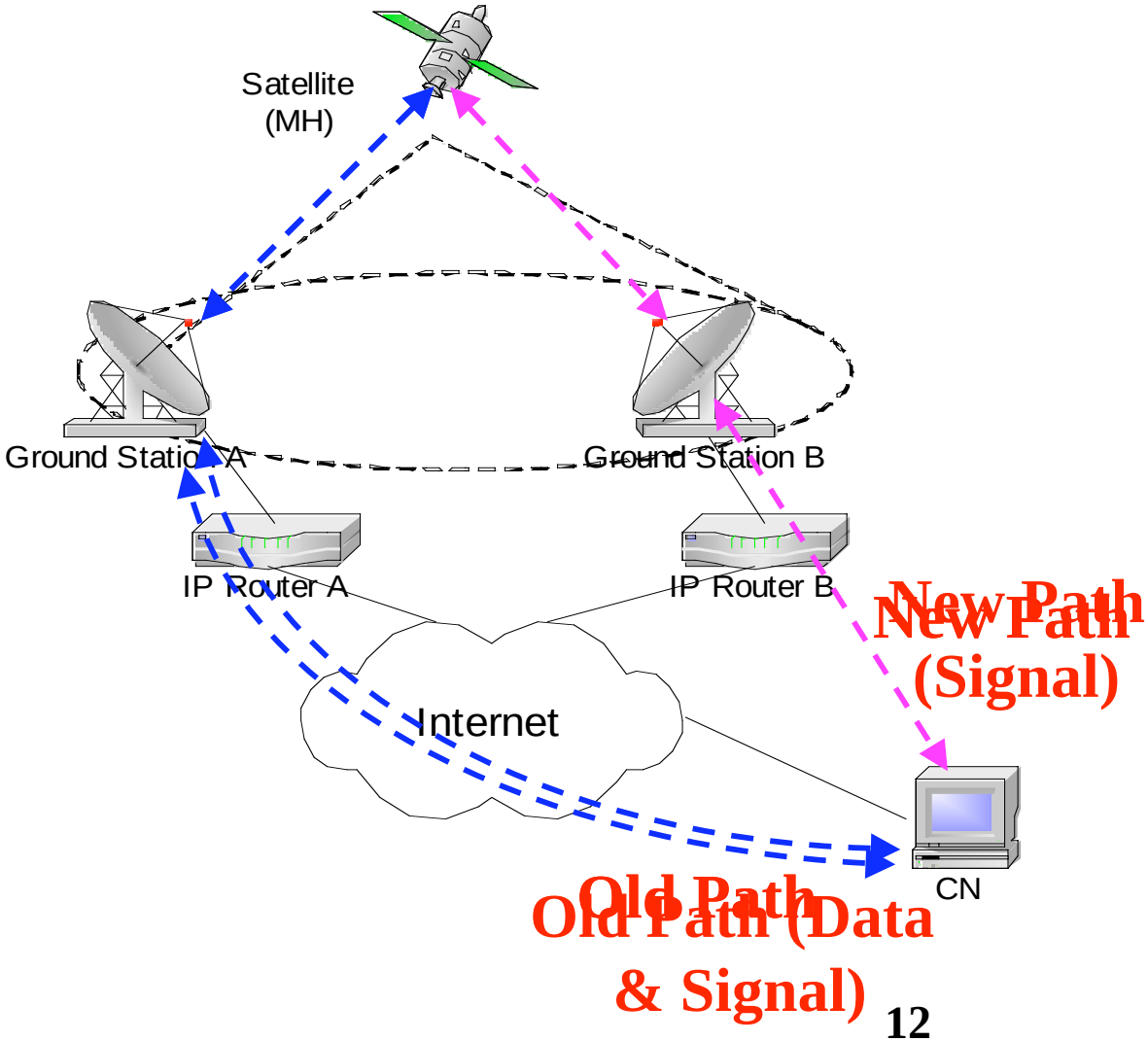
Spotbeam Handovers: Guaranteed vs. Prioritized

- Guaranteed Handover (GH) Schemes –
  - Ÿ Elastic Handover Scheme
  - Ÿ TCRA (Time based Channel Reservation Algorithm) based Handover Scheme
  - Ÿ DDBHP (Dynamic Doppler Based Handover Prioritization) Scheme

- Prioritized Handover (GH) Schemes –
  - Ÿ Handover with Guard Channel (HG)
  - Ÿ Handover with Queuing (HQ)
  - Ÿ Channel Rearrangement based Handover
  - Ÿ HQ + HG Handover

Network Layer Handovers: Classification

- Classification depending on the connection transfer process-
  - Ÿ Hard Handover Schemes – Mobile IP.
  - Ÿ Soft Handover Schemes
  - Ÿ Signaling Diversity Schemes - SIGMA.

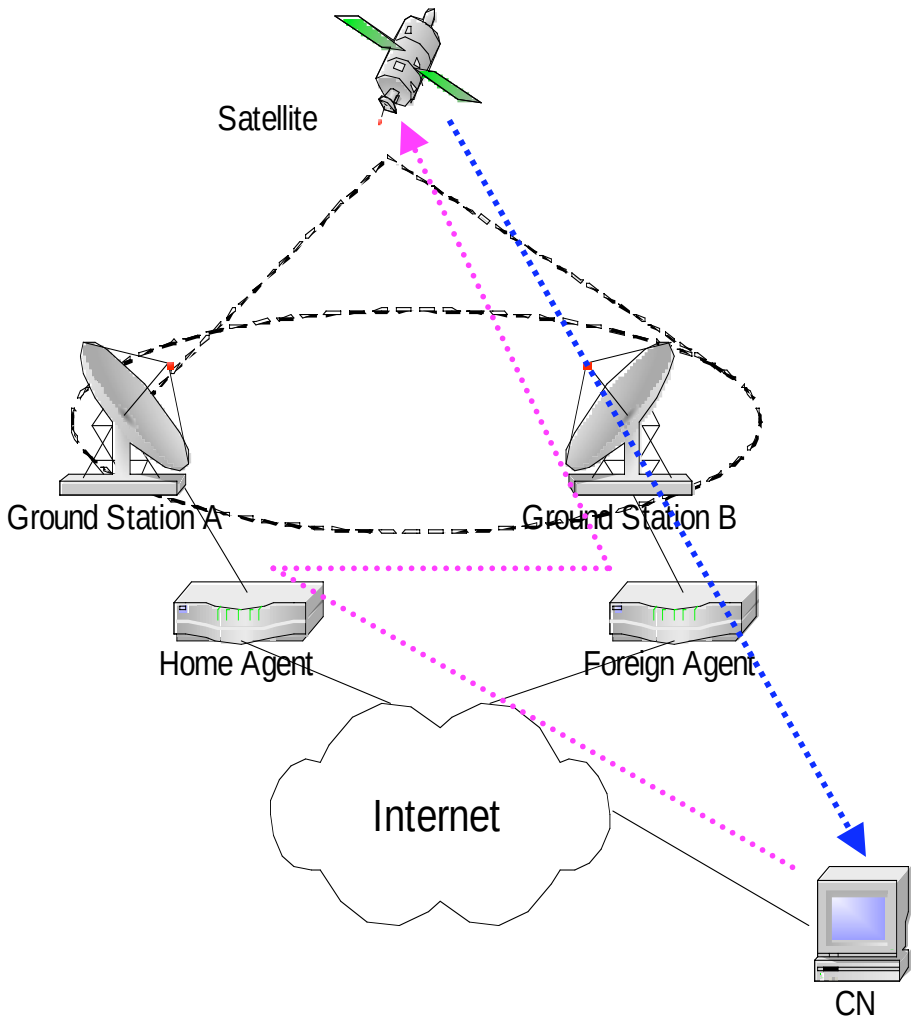


SIGMA: Motivation

- Several NASA projects related to IP in space and Mobile IP
  - Ÿ Global Precipitations Measurement (GPM)
  - Ÿ Operating Missions as Nodes on the Internet (OMNI)
  - Ÿ Communication and Navigation Demonstration on Shuttle (CANDOS)
  - Ÿ NASA currently working with Cisco on developing a Mobile router
- Mobile IP may play a major role in various space related NASA projects
  - Ÿ Advanced Aeronautics Transportation Technology (AATT)
  - Ÿ Weather Information Communication (WINCOMM)
  - Ÿ Small Aircraft Transportation Systems (SATS)
- University of Oklahoma and NASA jointly developed a seamless handover scheme called SIGMA
  - Ÿ applicable to both the satellite and wireless/cellular environment.

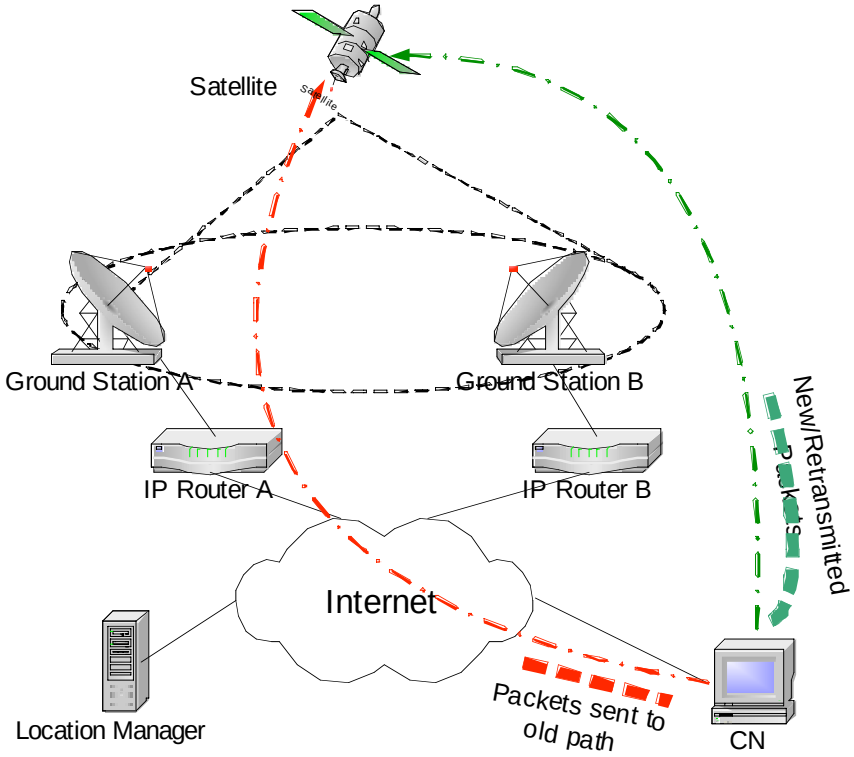
Major Drawbacks of Base Mobile IP

- Need modification to Internet infrastructure
- High handoff latency and packet loss rate
- Inefficient routing path
- Hard to duplicate HA to various locations to increase survivability and manageability
- Scalability issues



SIGMA: Basic concepts

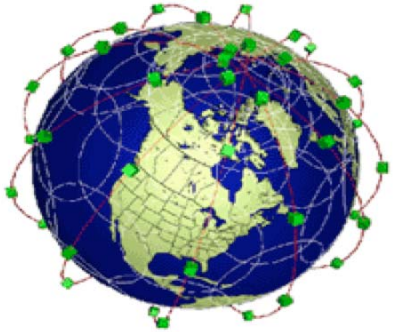
- Uses IP diversity for seamless handover
- Decouple location management from handover
- Almost no packet loss during handover
- Has no problem with IP security protocols
- Better Scalability and Survivability than Mobile IP
- Implementation:
  - Multihoming to achieve simultaneous communication with multiple access points.
  - Stream Control Transmission Protocol (SCTP).

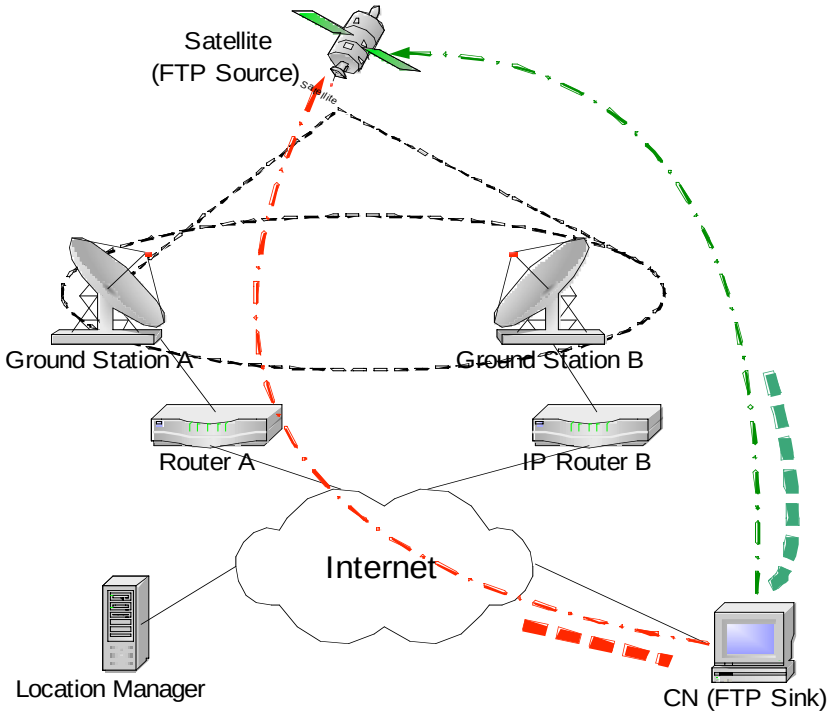


Satellite Simulation

SIGMA: Satellite Simulation Parameters

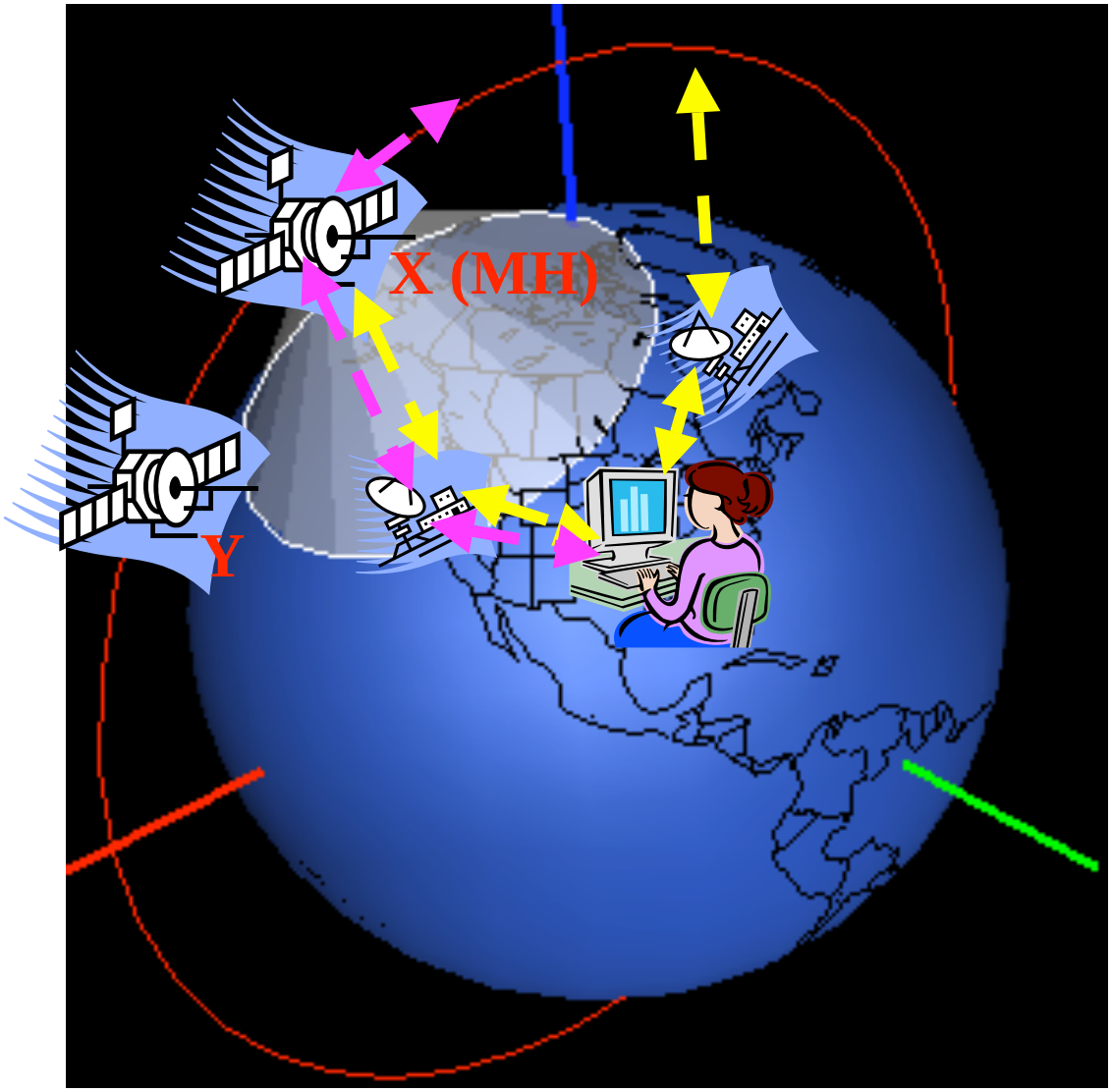
- Iridium like satellite constellation
- FTP file transfer between MH (satellite) and CN
- SCTP as underlying protocol





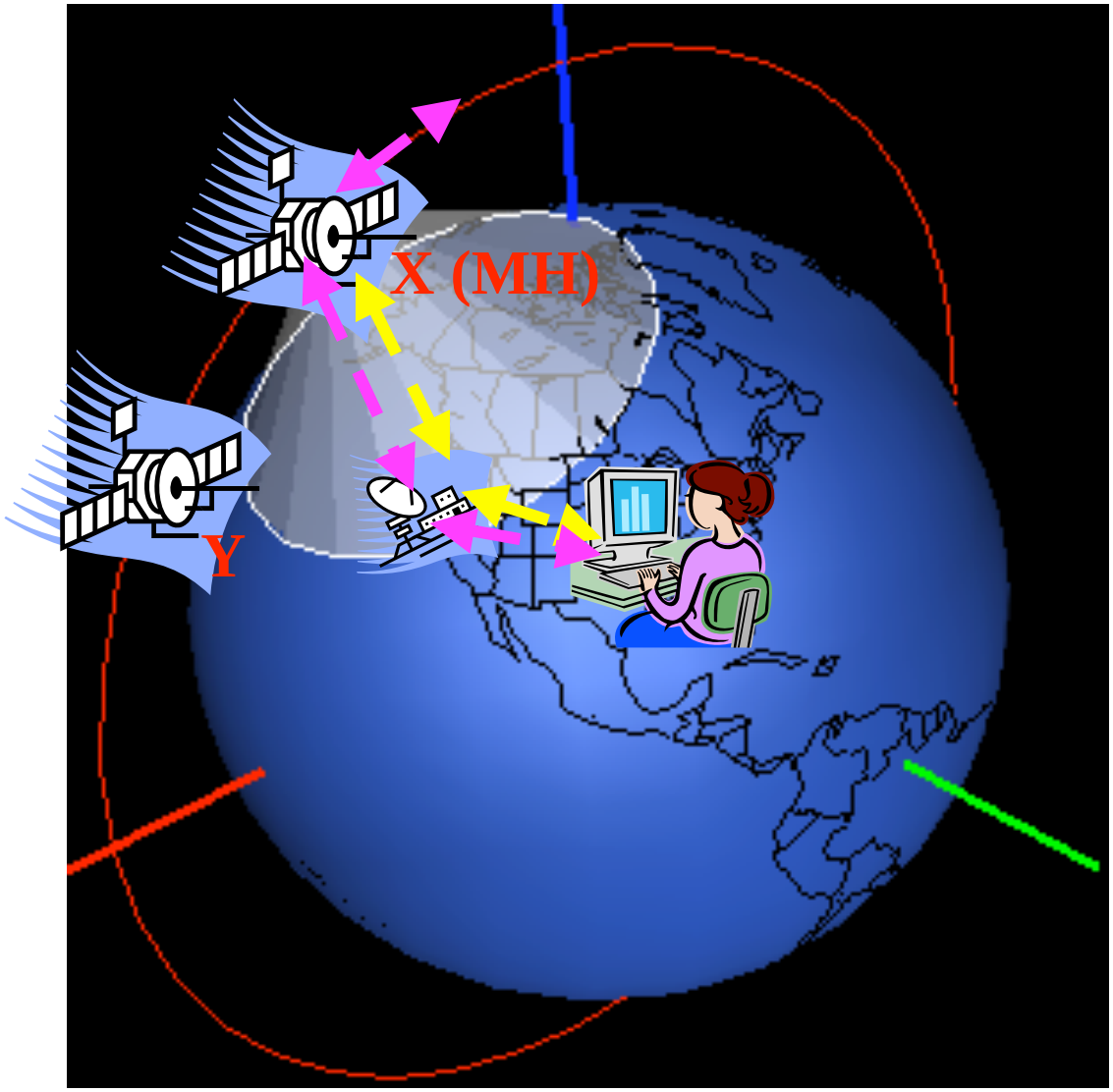
Simulation Scenario 1: Two Ground Station Constellation (TGSC)

- Two ground stations NOT under same satellite footprint.
- Satellite X (MH) transfers data through satellite Y using ISL when outside the range of both ground stations.



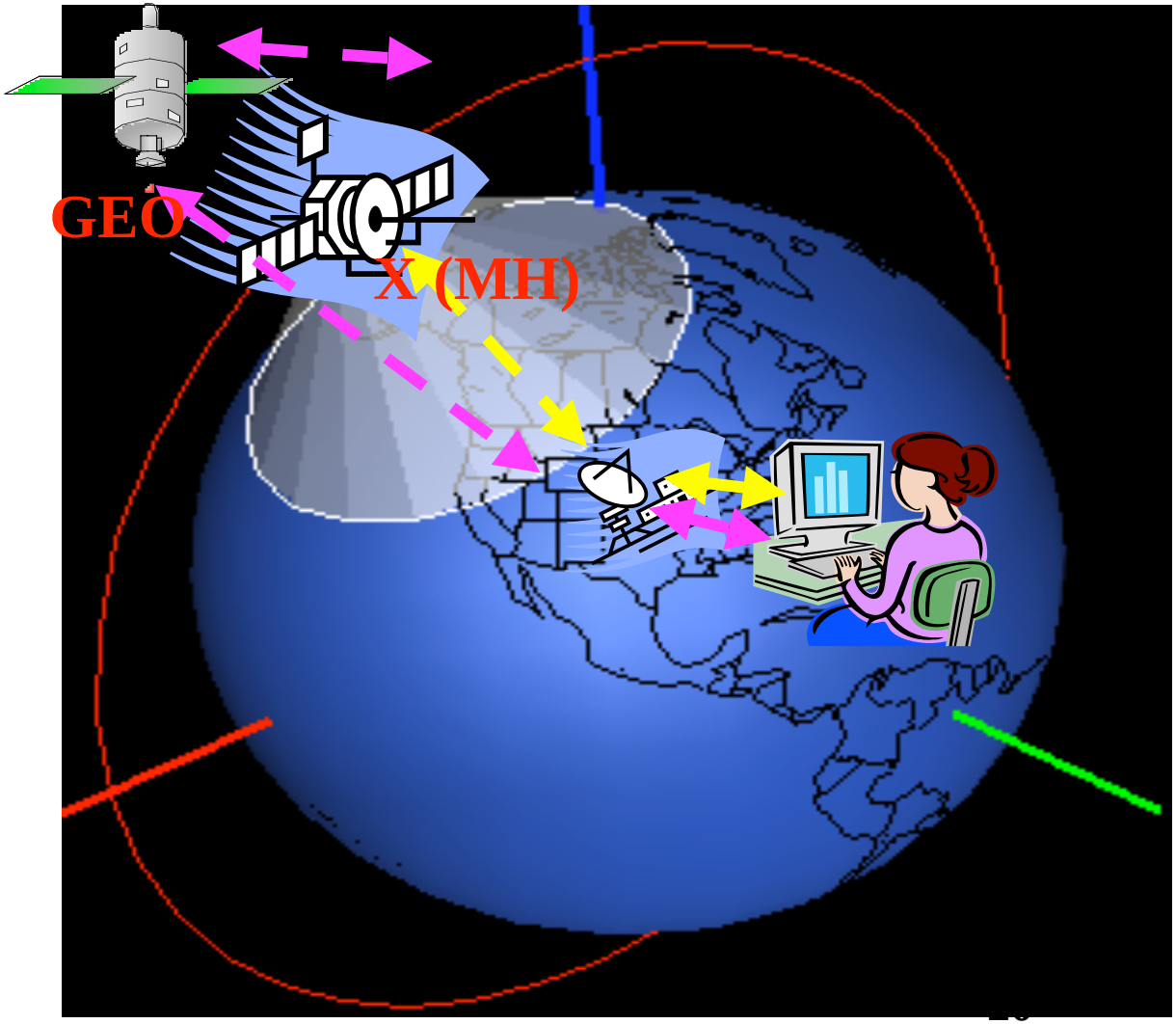
Simulation Scenario 2: One Ground Station Constellation (OGSC)

- Only ONE ground station can communicate with satellite.
- Satellite X (MH) can increase connectivity with the ground station using ISL through satellite Y.



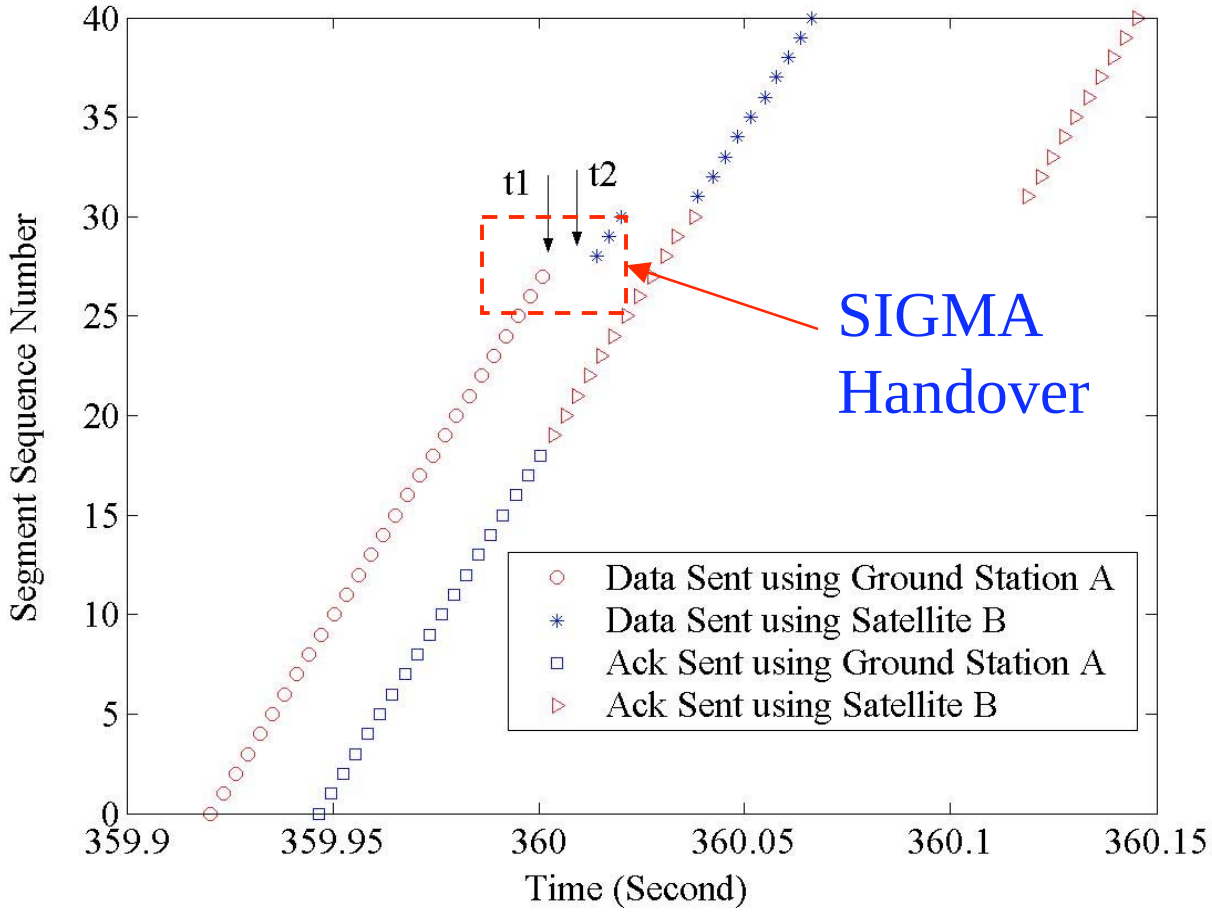
Simulation Scenario 3: Mixed LEO-GEO Constellation (MLGC)

- Only one ground station is capable to communicate with the satellite.
- While Satellite X (MH) is out of the range of ground station, it can send data through GEO satellite.

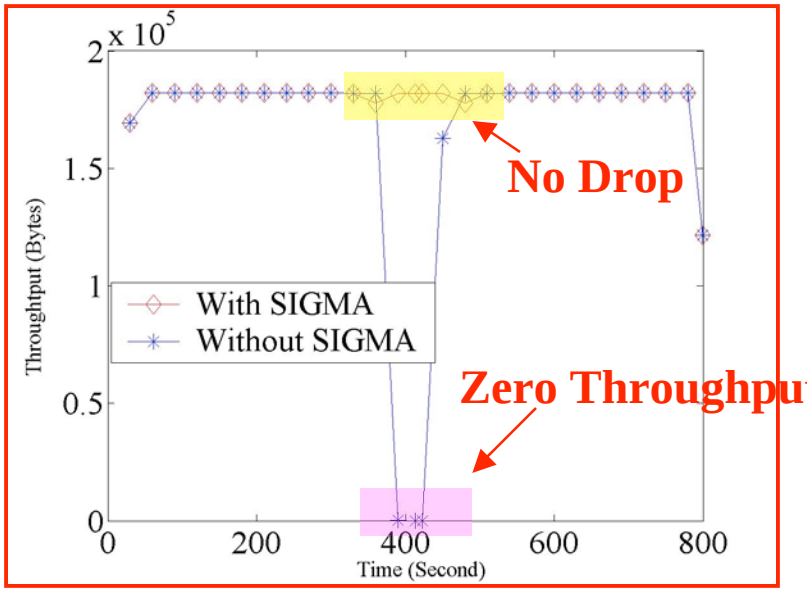


Results

- Time taken during SIGMA handover (t_2-t_1) is very small
- Seamless handover in SIGMA is achieved using IP diversity

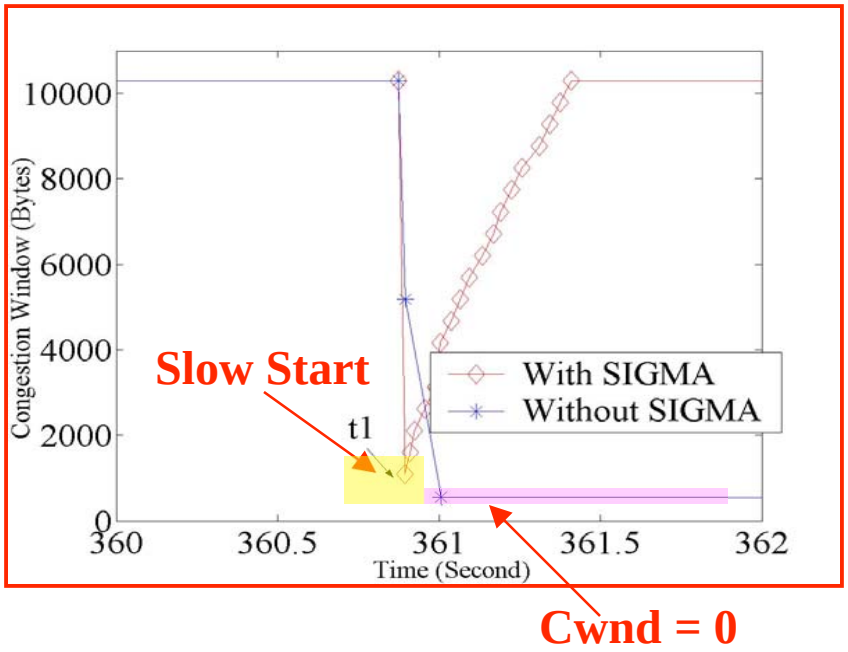


Throughput



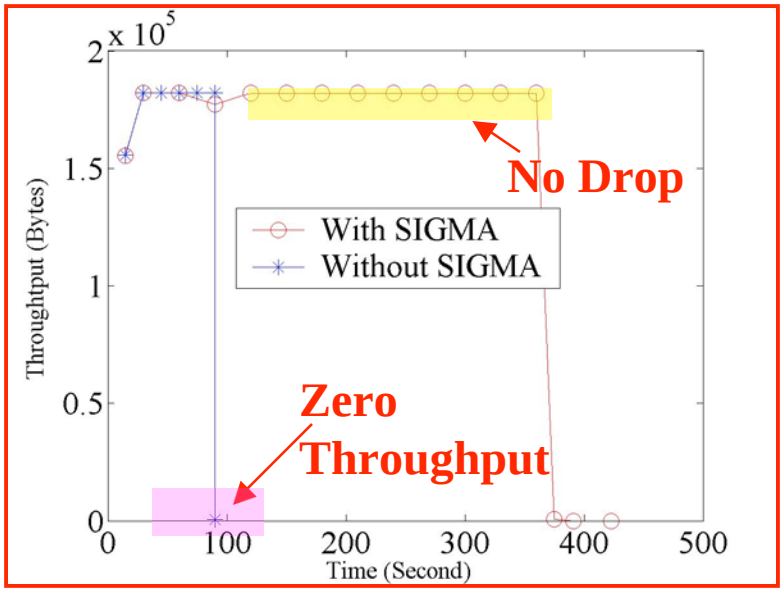
- With SIGMA, no drop in Throughput

Congestion Window



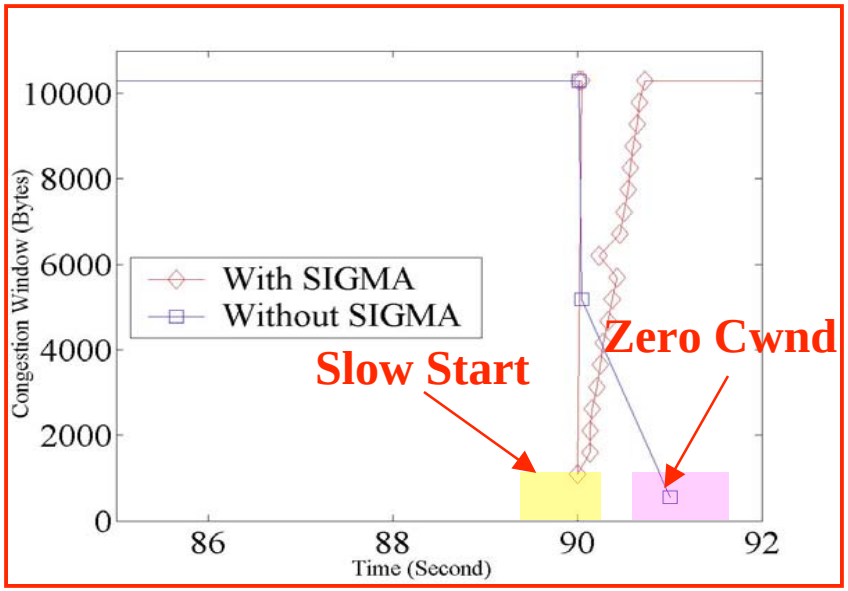
- Slow start (at t_1) during SIGMA handover
- Congestion window goes to zero without SIGMA

Throughput



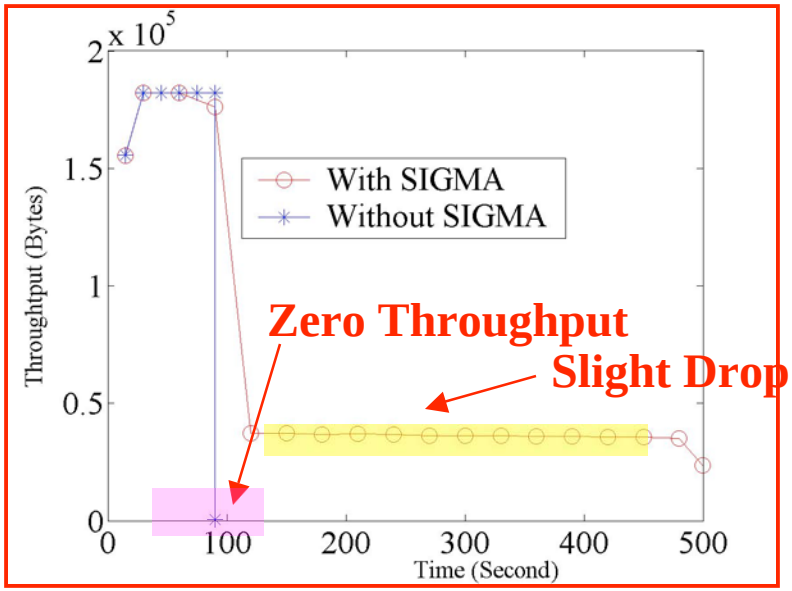
- With SIGMA, network connectivity extends till 400 sec.
  - Ÿ Without SIGMA, throughput drops to zero at 100 sec.

Congestion Window



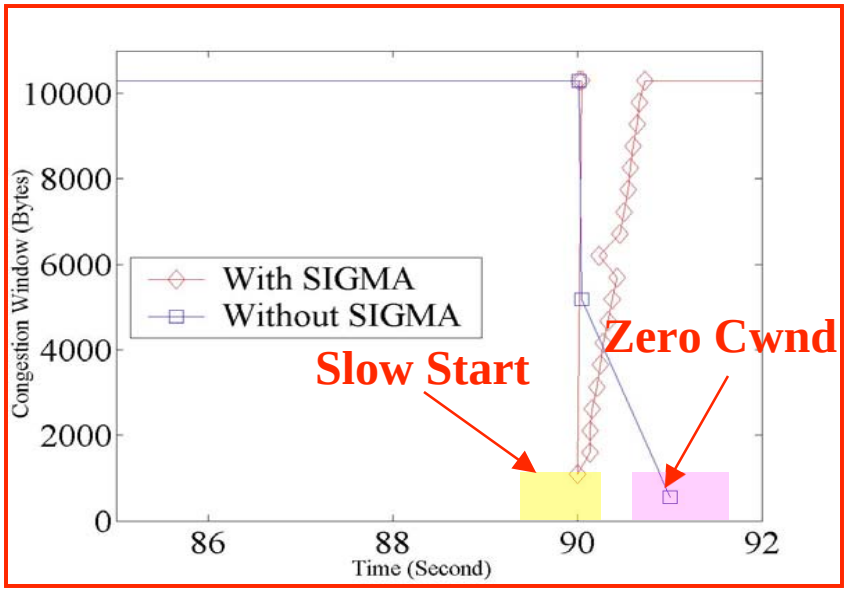
- Slow start in Congestion window during SIGMA handover while without SIGMA it drops at 90 sec.

Throughput



- With SIGMA, after handover drop in Throughput due to change of path through GEO satellite
- Without SIGMA, throughput goes to zero.

Congestion Window

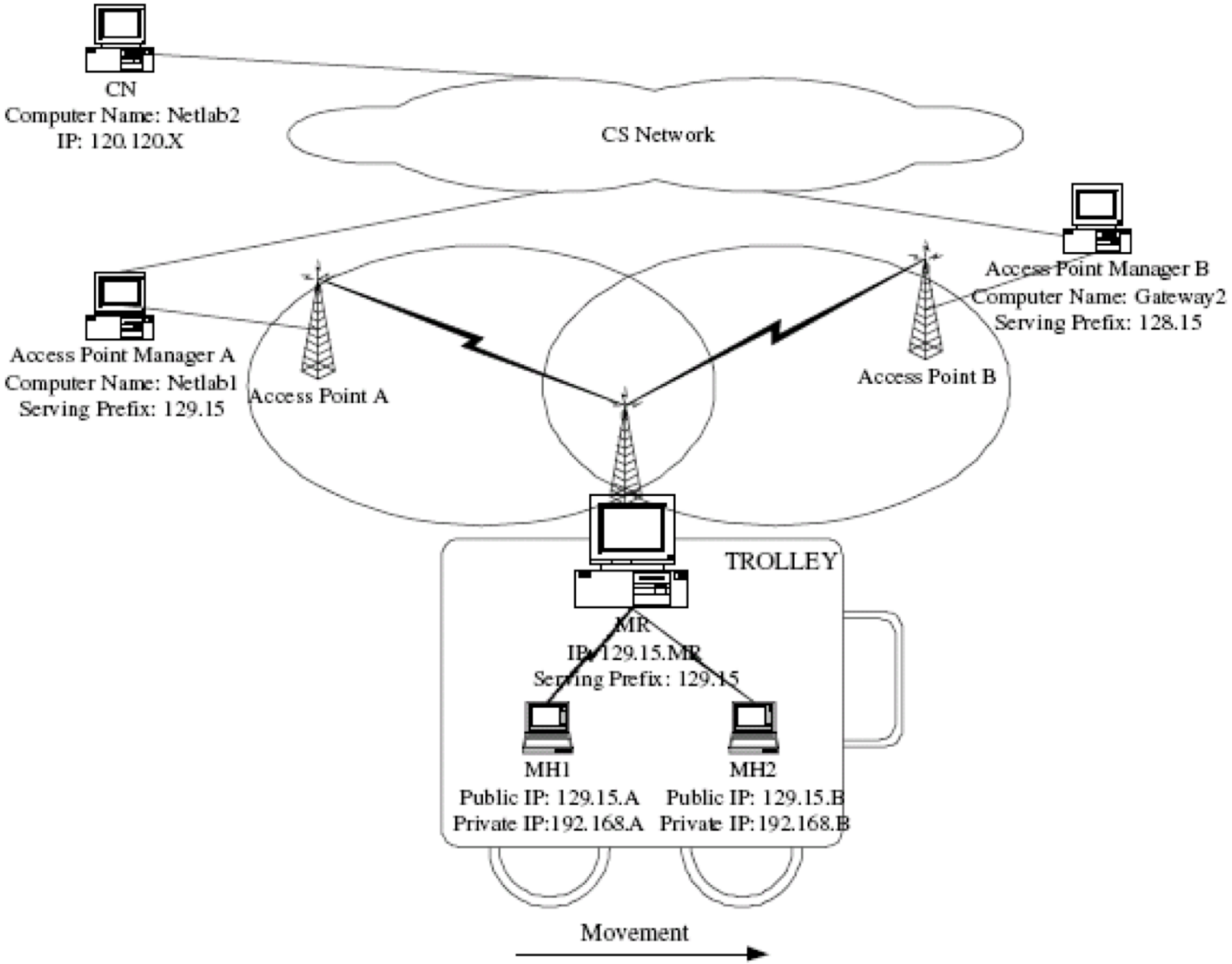


- Slow start in Congestion window during SIGMA handover while without SIGMA it drops at 90 sec.

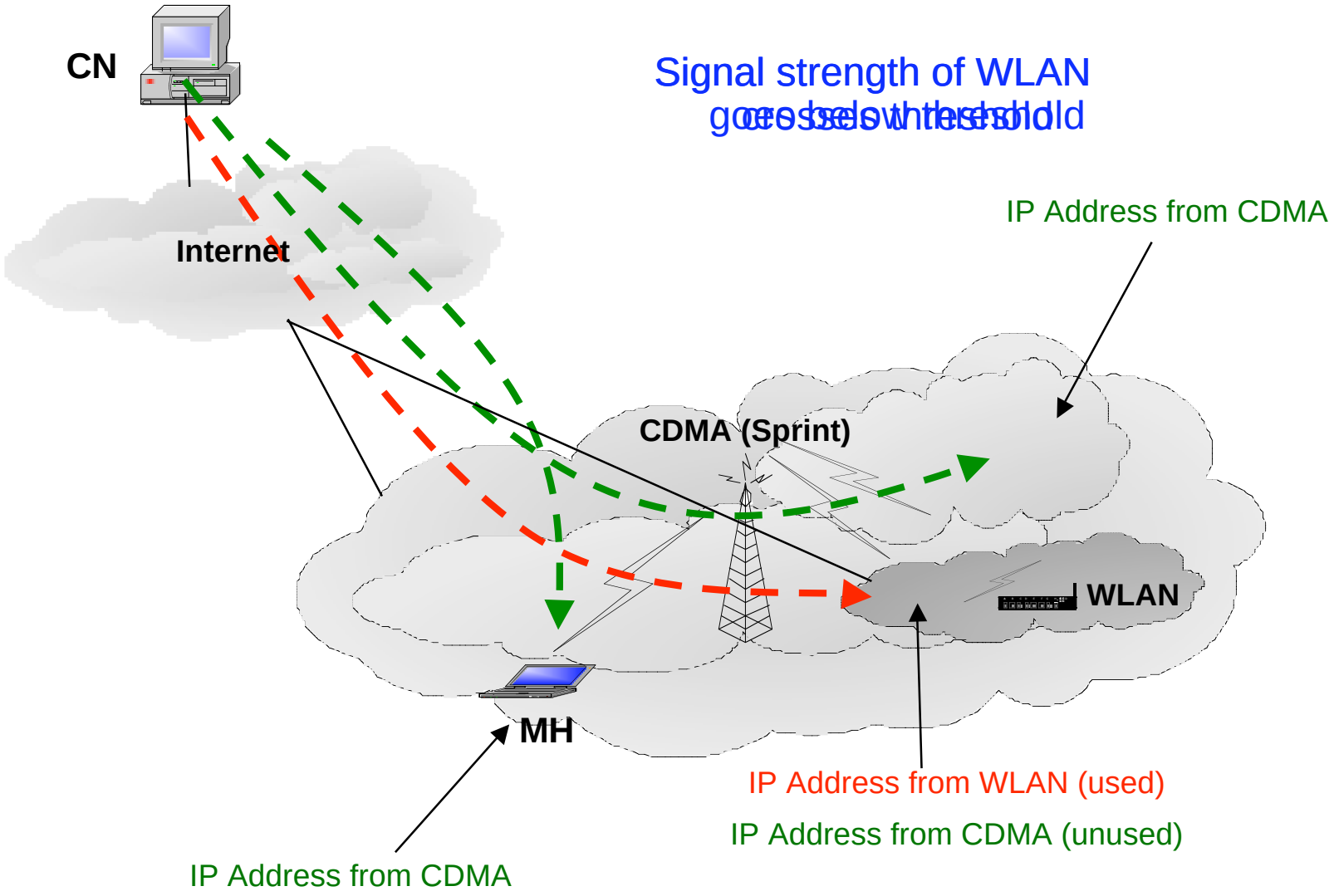
Future Work

- Seamless IP-diversity based NEtwork MObility (SINEMO)
- Real time space testing of SIGMA using Surrey Satellite Technology satellite
- Vertical handoff between heterogeneous technologies

SI-NEMO: SIGMA Network in Motion



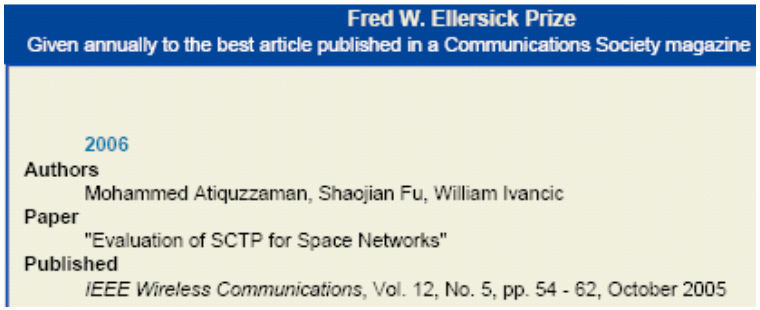
Vertical handoff with SIGMA



Project Impact

- Advancement
  - Ÿ Expect to move from TRL 3 to TRL 5 at end of project
- Recognition
  - Ÿ News article in local newspaper
  - Ÿ Interview broadcast on radio station
  - Ÿ Best paper award from IEEE
  - Ÿ 17 journal and conference papers, 21 technical reports
  - Ÿ One IETF standards contribution
- External Collaboration/Broader Impact
  - Ÿ Harsha Sirisena (Univ of Canterbury, New Zealand)
  - Ÿ Wes Eddy (NASA Glenn)
  - Ÿ Joe Ishac (NASA Glenn)
  - Ÿ Dilip Sarkar (Univ. of Miami)
- Graduate education
  - Ÿ 2 PhD, 3 MSc (completed + in progress)

A weekly radio program about higher education in Oklahoma



Acknowledgements

- NASA and program managers for funding this project.
- Team Members

www.cs.ou.edu/~netlab